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NIF Beam Shaping Masks

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Lawrence
Livermore
National
Laboratory

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To: Emmanuel Marquis
From: Mark Bowers
Subject: NIF beam shaping masks

Your question was not as simple to answer as I had first suspected. We were working through some issues with how the shapers/apodizers were being used and I did not want to give you incorrect information. They are designed to have somewhat high loss through the first pinhole and that was causing some confusion in the multipass amplifier. That issue has been straightened out and this information is correct. There are three attachments that will explain a little more about how the spatial shapers work. But the main point is that they are binary masks (0 or 100% transmission). The pattern of the 24x24 μm hole determines the overall transmitted spatial intensity. It is important to note that there is a lot of high frequency noise until the first spatial filter (for us it is 100 μrad related to the 372 mm beam size). This first filter does take out almost all of the high frequency noise and leave a very nice beam. Of the three attachments, two explain how the apodizer works and one shows a binary image that we transfer onto a glass plate with Chromium.

We are using Sine Patterns

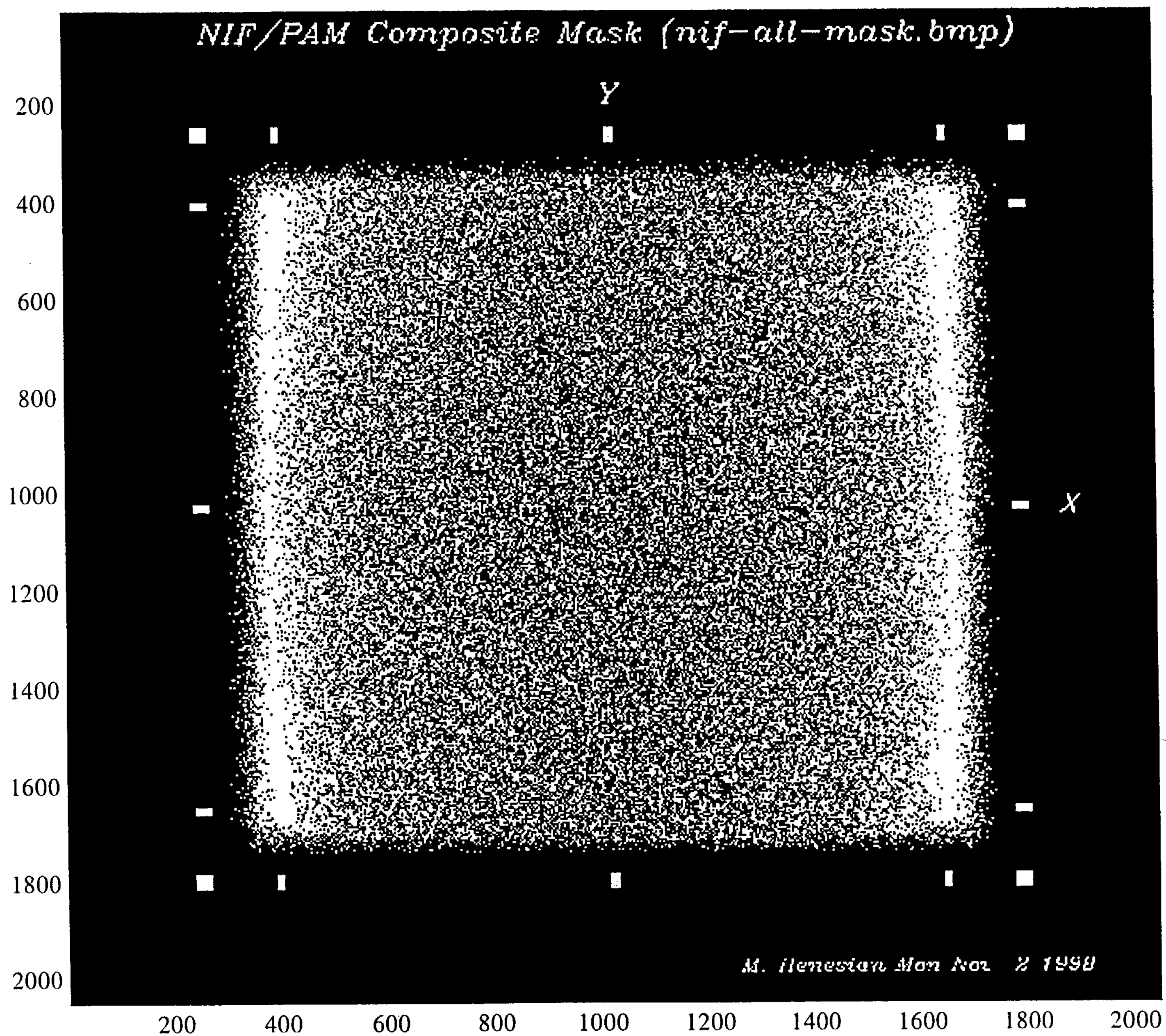
SINE PATTERNS LLC
Pittsford, NY 14534
Phone: (716) 385-1110 Fax: (716) 385-9528
http://www.sinepatterns.com/

with much success. They can create two kinds of masks for us. The first kind is on their standard substrate and without AR coatings. We then coat these with a sol-gel AR coating in-house. These take a 1-2 weeks for delivery. I don't have a good price on those. The other masks are on "NIF" qualified glass and have a hard AR coating under the Chromium. These are more expensive and take 20 weeks ARO. The price from them has been $1600 (US) each.

Please feel free to contact me if you have more questions and again, sorry for the delay.

Best Regards,

Mark Bowers



NIF/PAM Composite Mask (nif-all-mask.bmp)
Y
X
200
400
600
800
1000
1200
1400
1600
1800
2000
M. Henesian Mon Nov 2 1998

Inertial Confinement Fusion Program
ICF Laser Science and Technology
Laser Modeling and Optimization Group

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June 7, 1999
LST-LMO-99-012
NIF-0025092
W.B.S. 1.3.1

To: Distribution
From: Mark A. Henesian
Subject: NIF beam shaping mask specifications

Summary: the enclosed e-mail describes the predicted transmission specifications on the four manufactured PAM/NIF spatial shaping masks (described below). Color contour and surface plots are attached for the analytic transmission profile of each mask.

Date: Sat, 05 Jun 1999 16:44:53 -0700
To: hermann1@llnl.gov, crane1@llnl.gov, moran5@llnl.gov, martinez31@llnl.gov, skulina1@llnl.gov
From: "Mark A. Henesian" <henesian1@llnl.gov>
Subject: NIF Beam Shaping Mask Specifications
Cc: hackel2@llnl.gov, aikens1@llnl.gov, sacks1@llnl.gov, wwilliams@llnl.gov, lawson3@llnl.gov, henesian1@llnl.gov

Shaping description and mask transmission specifications:

Attached are color contour and surface profile pictures of the four spatial shaping masks required for PAM testing. The masks have been described previously (e-mail sent Jan 7, 1999 and document **NIF-0023967** dated May 26, 1999). These pictures were derived from the binary patterns and represent the transmission after spatial filtering in the PAM. The masks have been calculated for a 32 x 32 mm beam footprint, which allows some beam size margin, and also the ability to "tune" the shape by small side-ways translation in the PAM shaping module. Note that each mask requires a serrated apodizer to define the beam edge - each mask used alone will roughly apodize the elliptical gaussian regen beam at the ~31 x 31 mm size.

The binary chrome-on-glass patterns were transferred to Photosciences in Torrance, CA., who manufactured two (?) of each design. The binary patterns (in PC 8-bit binary file format) were each 4 MB in size and were 2048 x 2048 pixels in width and height, each pixel was 24 x 24 microns. The binary patterns were designed to compensate for the diffraction loss over and above the obscuration loss of the chrome pixels. These new spatial shaper designs, when hard AR coated, should get us very close to the theoretical energy transmissions (compiled below).

The masks are described below with center and overall transmission values for a "flat" 30 x 30 mm test beam used with the TAB 10 error function serrated beam edge-apodizer.

1.) **"ellipt-mask":** used to convert 39 x 33 mm fw1/e regen beam to a flat shape at the shaping module relay plane. Center reference transmission=26.0%, Energy transmission=40.6%, Peak/Center transmission ratio=2.856.

2.) **"pam-mask":** used to convert 39 x 33 mm fw1/e regen beam to a flat output shape at the RP8 relay plane of the 4-pass amplifier over the entire operating range (1 to 16+ joules). Center reference transmission=66.1%, Energy transmission=75.9%, Peak/Center transmission ratio=1.417.

3.) **"nif-mask":** used in conjunction with "pam-mask" to convert the 39 x 33 mm fw1/e regen beam to a flat output shape at the NIF output relay plane (KDP plane) over the full range of NIF energies for the SSMP and ICF missions. Output shape is "flat" at low energy (1-kJ/beamline) and slightly convex at high energy (20 kJ/beamline). Center reference transmission=18.6%, Energy transmission=27.5%, Peak/Center transmssion ratio=3.074. When used with "pam-mask" energy transmisssion is approx. 18.1%.

4.) **"nif-all-mask":** a high efficiency composite profile used individually to convert the 39 x 33 mm fw1/e regen beam to a flat output shape at the NIF output relay plane (KDP plane) over the full range of NIF energies for the SSMP and ICF missions. Same output shape as using "pam-mask" and "nif-mask" together. Center reference transmission=13.7%, Energy transmission=23.7%, Peak/Center transmission ratio=4.250.

Performance Summary <u>(when masks are used with 39 x 33 mm elliptical gaussian regenerative amplifier beam)</u>:

1.) For "flat" beam at shaping module output using the **"ellipt-mask"**, the energy transmission of the mask is predicted to be <u>20.1%</u>.

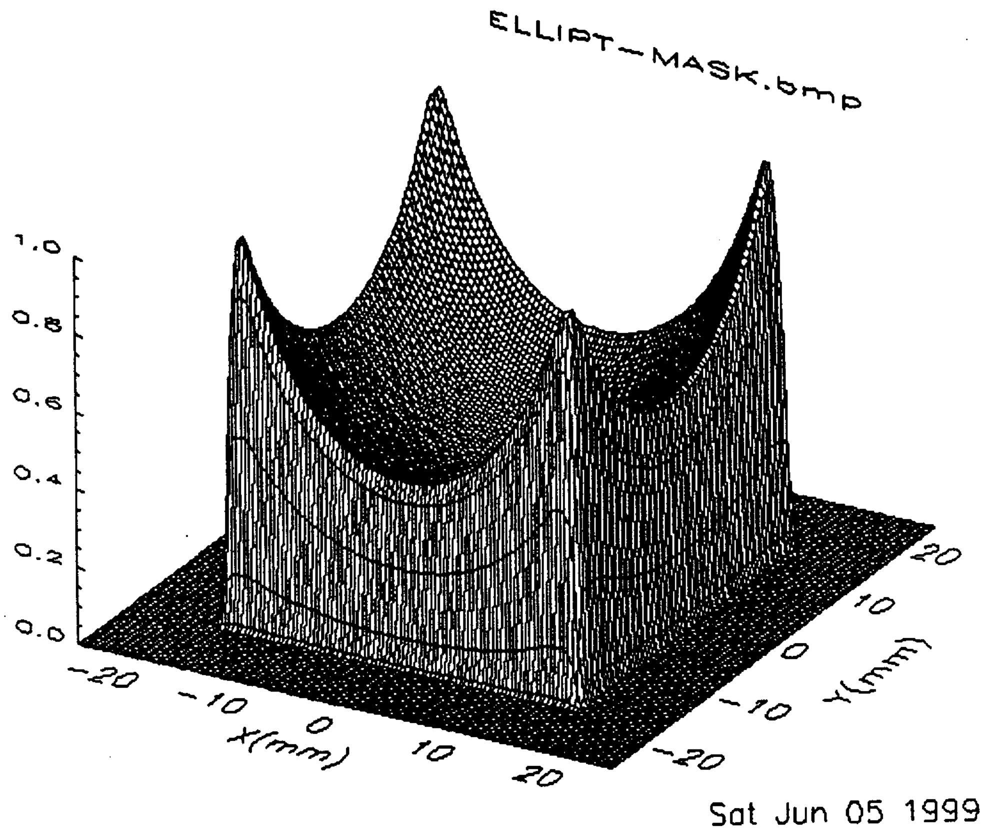
2.) For "flat" output at RP8/RP10 using the **"pam-mask"**, the energy transmission of the mask is predicted to be <u>47.3%</u>.

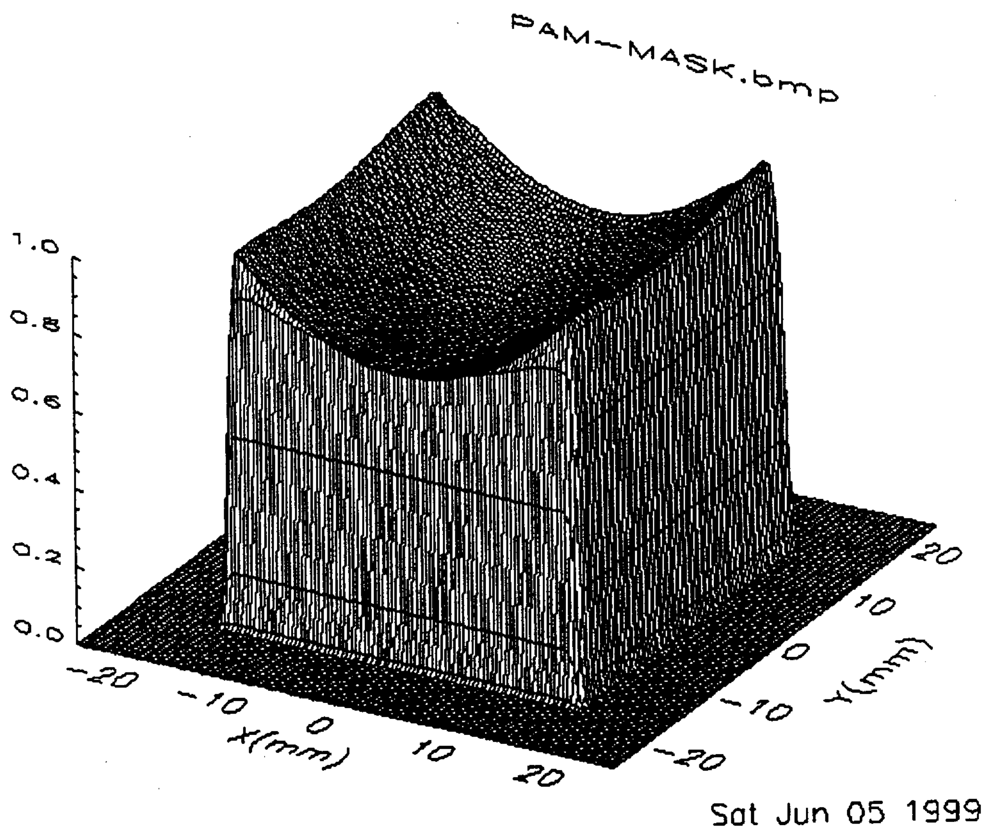
3.) For "flat" output at NIF KDP plane using the **"nif-all-mask"**, the energy transmission of the mask is predicted to be <u>11.4%</u>

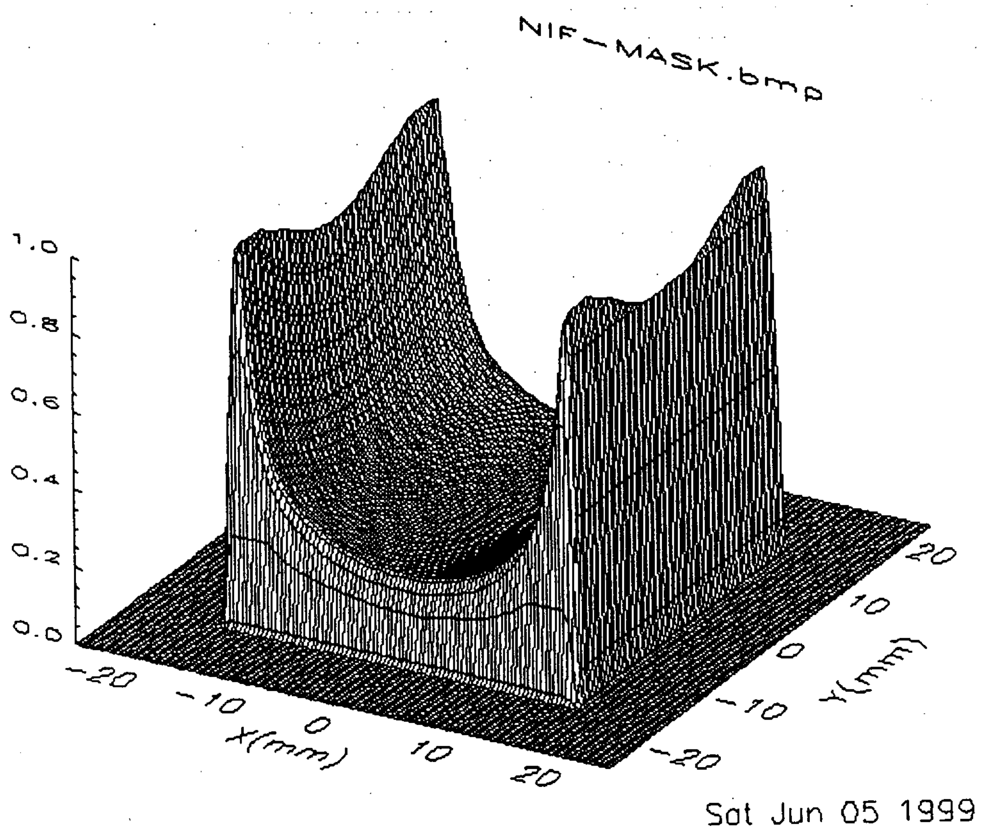
4.) Fot "flat" output at NIF KDP plane using the combination of the **"pam-mask"** + **"nif-mask"**, the overall energy transmission of the combination is predicted to be <u>10.3%</u>

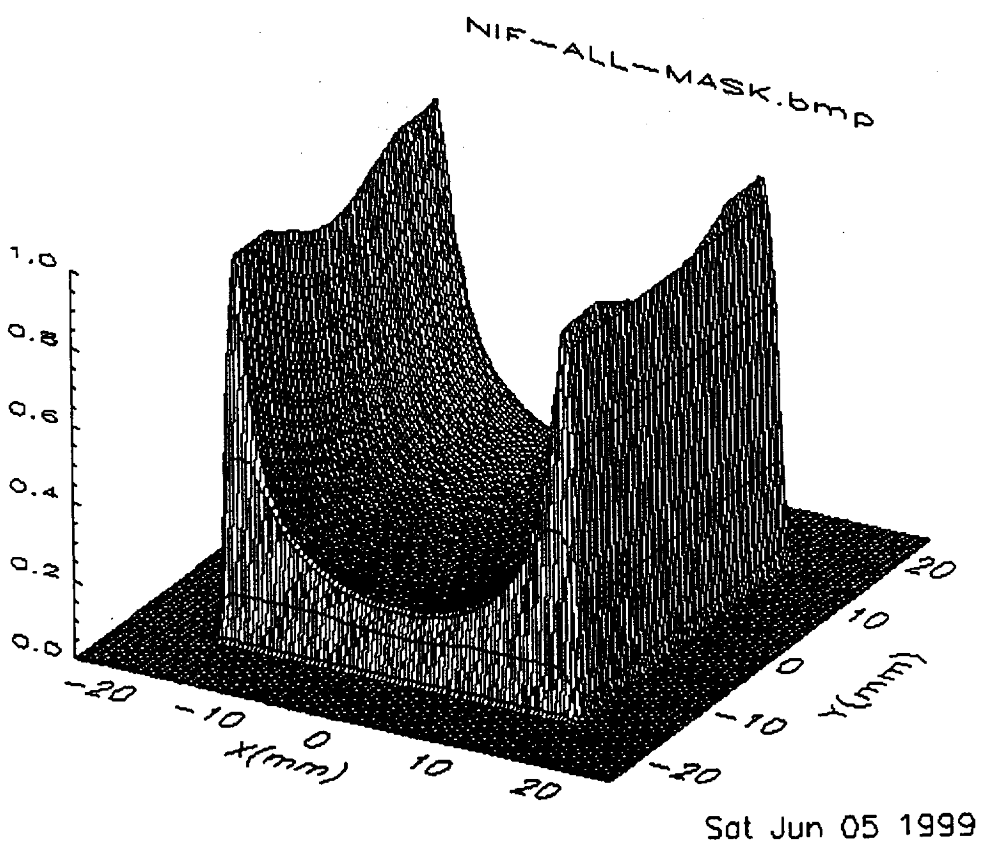
These transmissions assume that the shaping masks are used with the TAB 10 serrated apodizer. With the "softer" edged TAB 11 and TAB 12 designs (**NIF-0015283** document, dated October 11, 1998) the overall shaping efficiency will be reduced.

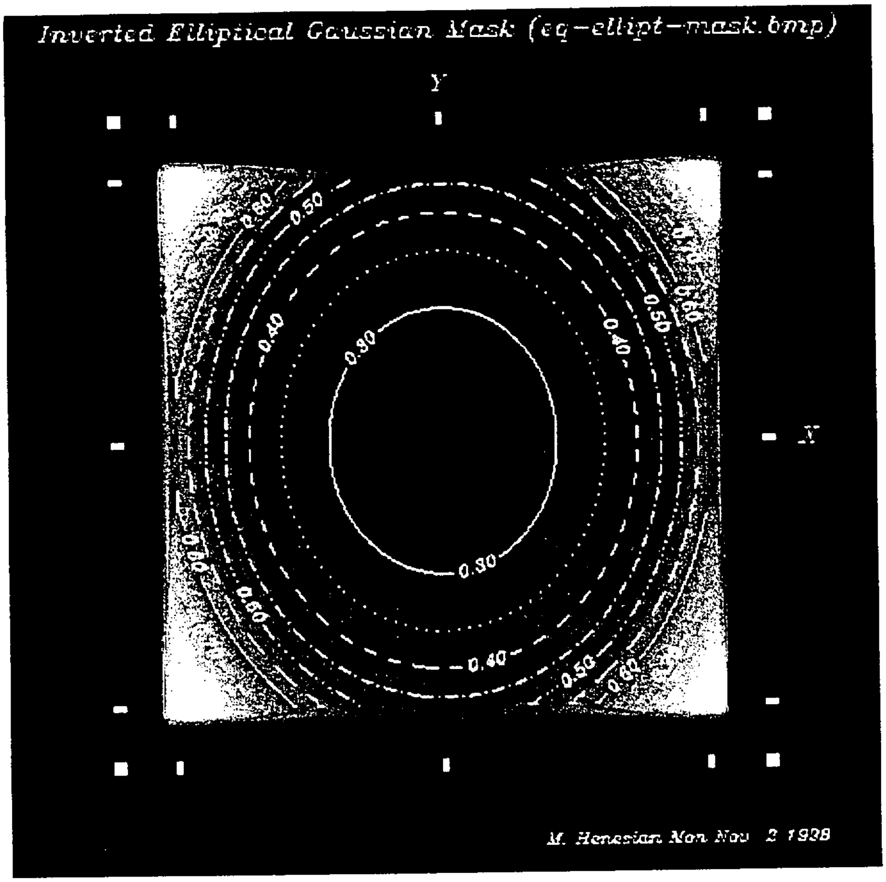
Mark Henesian 6/5/99

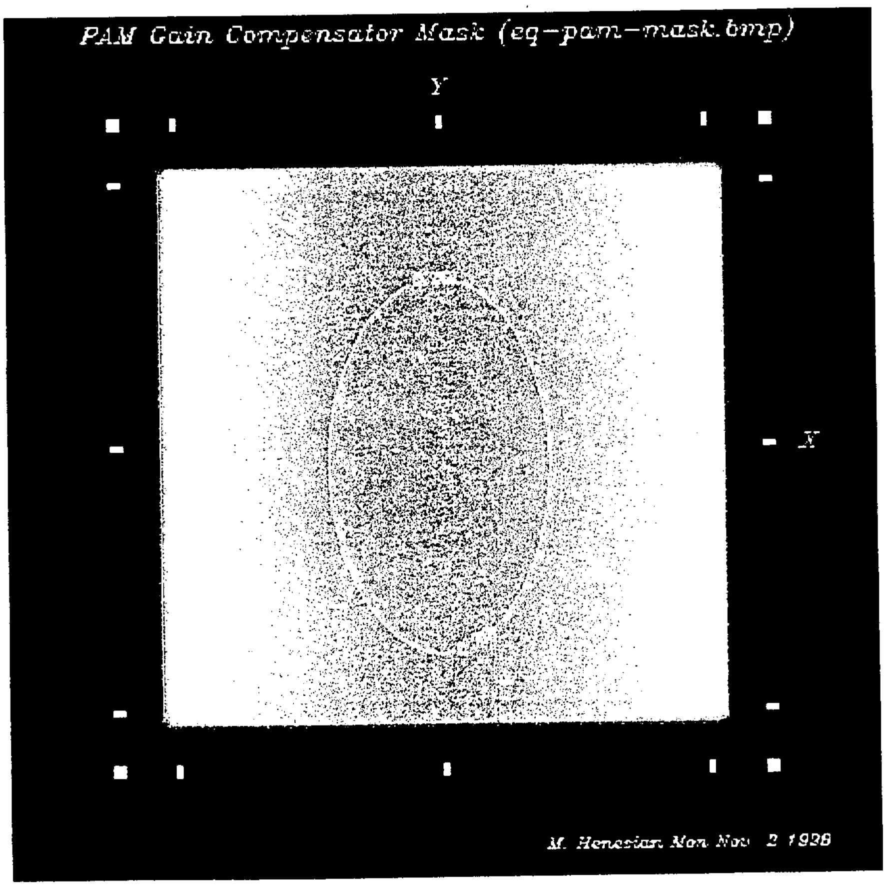

ELLIPT—MASK.bmp
1.0
0.8
0.6
0.4
0.2
0.0
−20
−10
0
X(mm)
10
20
Y(mm)
Sat Jun 05 1999

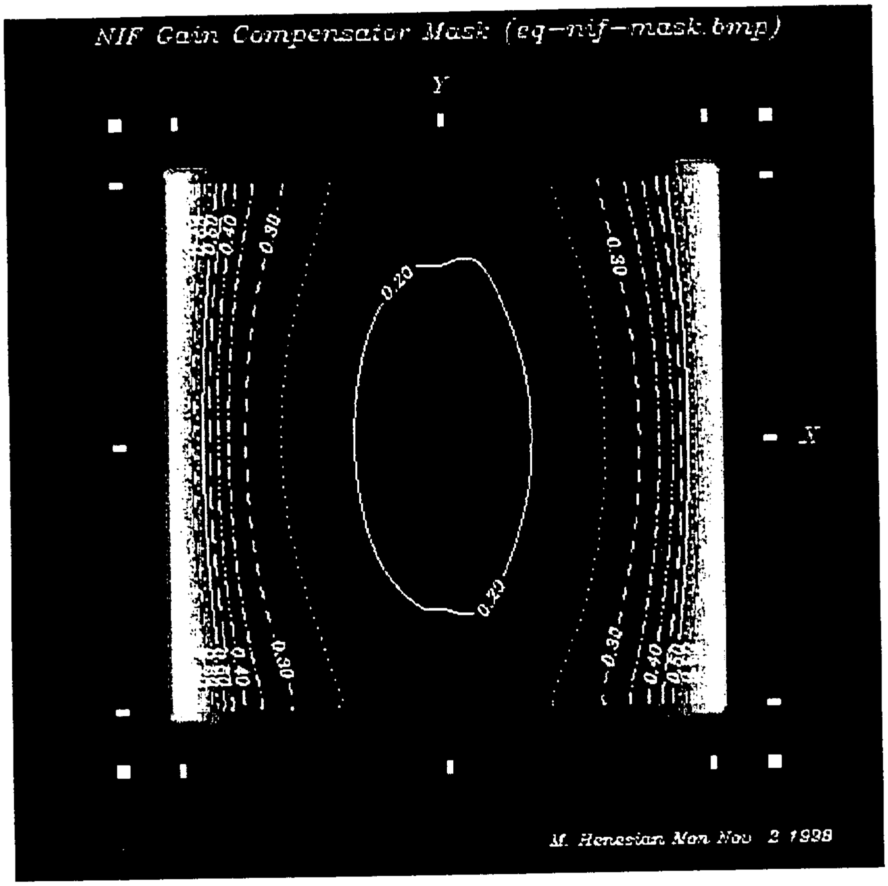

PAM—MASK.bmp
1.0
0.8
0.6
0.4
0.2
0.0
−20
−10
0
X(mm)
10
20
Y(mm)
Sat Jun 05 1999


NIF-MASK.bmp
1.0
0.8
0.6
0.4
0.2
0.0
-20
-10
0
10
20
X(mm)
-20
-10
0
10
20
Y(mm)
Sat Jun 05 1999


NIF-ALL-MASK.bmp
1.0
0.8
0.6
0.4
0.2
0.0
-20
-10
0
10
20
X(mm)
-20
-10
0
10
20
Y(mm)
Sat Jun 05 1999


Inverted Elliptical Gaussian Mask (eq-ellipt-mask.bmp)
Y
X
0.60
0.50
0.40
0.30
M. Henesian Mon Nov 2 1998


PAM Gain Compensator Mask (eq-pam-mask.bmp)
Y
X
M. Henesian Mon Nov 2 1998


NIF Gain Compensator Mask (eq-nif-mask.bmp)
Y
X
0.40
0.30
0.20
0.20
0.30
0.40
0.30
0.30
0.40
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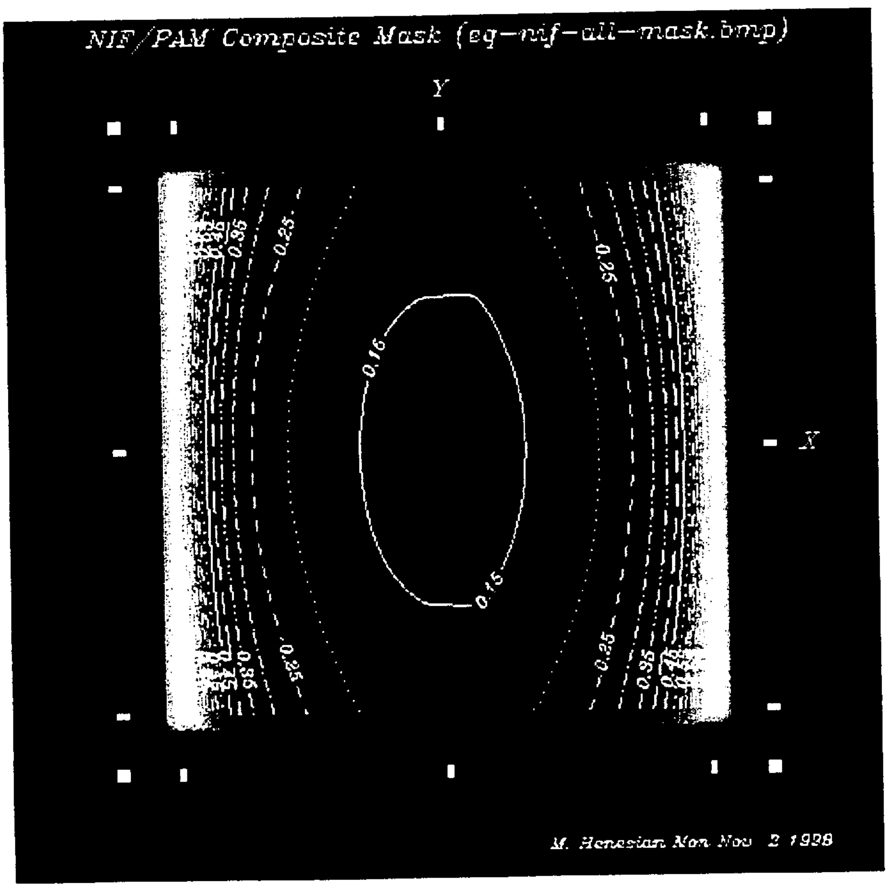
NIF/PAM Composite Mask (eq-nif-all-mask.bmp)
Y
X
0.35
0.25
0.16
0.16
0.25
0.35
0.25
0.25
0.35
M. Henesian Mon Nov 2 1998

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May 26, 1999
LST-LMO-99-011
NIF-0023967
W.B.S. 1.3.1

To: Distribution
From: Mark A. Henesian
Subject: NIF and PAM beam shaping mask descriptions

Summary: the following mask specifications need to be incorporated in an updated AAA-97-106261 drawing package, entitled "OPG/Injection Laser System Beam Shaping Filters".

Date: Thu, 07 Jan 1999 12:52:51 -0800
To: skulina1@llnl.gov, crane1@llnl.gov, hermann1@llnl.gov, moran5@llnl.gov, martinez31@llnl.gov
From: "Mark A. Henesian" <henesian1@llnl.gov>
Subject: Beam Shaping Mask Nomenclature/Summary
Cc: english2@llnl.gov, aikens1@llnl.gov, henesian1@llnl.gov, trenholme1@llnl.gov

NIF/PAM Shaping Mask Summary:

The masks are designed for a 30 x 30 mm beam in the PAM, but are slightly oversize (not much) to allow some beam size margin, and to "tune" the shape somewhat by small side-ways translation in the PAM shaping module. Note that each mask requires a serrated apodizer in order to accurately define the beam edge - each mask used alone will only roughly apodize the elliptical gaussian regen beam. Alignment markings have been added to the mask patterns to allow accurate centering with crosshairs and X-Y orientation in the shaping module. The X-Y coordinates match those on the NIF 4-pass amplifier drawing.

The binary chrome-on-glass patterns are 2048 x 2048 pixels in width and height, each pixel is 24 x 24 microns. The patterns are designed to compensate for diffractive loss over and above the obscuration loss of the chrome (black) pixels, and should get us close to the theoretical energy transmissions possible when hard-AR coated.

Nomenclature:(as encoded on each mask)

*1.) **Inverted elliptical gaussian mask*** ("ellipt-mask.bmp"): used to convert the 39 x 33 mm fw1/e regen beam to a flat output shape at the shaping module relay plane RP0. <u>This mask is for test only - will not be used on NIF.</u>

*2.) **PAM gain compensator mask*** ("pam-mask.bmp"): used to convert regen beam to a flat output shape at the RP8 relay plane of the 4-pass amplifier over the operating range (1 to 16+ joules).

*3.) **NIF gain compensator mask*** ("nif-mask.bmp"): used in conjunction with "pam-mask" to convert regen beam to a flat output shape at the NIF output plane (KDP plane) over the full range of NIF energies for the SSMP and ICF missions. Output shape is "flat" at low energy (1-kJ/beamline) and slightly convex at high energy (20 kJ/beamline).

4.) NIF/PAM composite mask ("nif-all-mask.bmp"): a high efficiency composite profile used individually to convert the regen beam to a flat output shape at the NIF output relay plane (KDP plane) over the full range of NIF energies for the SSMP and ICF missions. Same output shape as using "pam-mask" and "nif-mask" together.

Efficiencies:

1.) "pam-mask": for "flat" output at RP8/RP10 the overall energy transmission from regen output (not including losses in regen transport optics and 20X Newport telescope lenses, diagnostics splitter, temporal pulse slicer, etc.) to the beam shaping module output plane is 47.25%.

2.) "nif-all-mask": for "flat" output at NIF KDP plane, the overall energy transmission from regen output (not including losses above,etc.) to the beam shaping module output plane is 11.42%

3.) "pam-mask" + "nif-mask": for "flat" output at NIF KDP plane, etc, efficiency is 10.28%

The shaper efficiency estimates assume that the masks are used with the TAB 10 serrated apodizer. With the "softer" edged TAB 11 and TAB 12 designs the overall efficiency will be reduced. Used alone, the inverted elliptical gaussian mask will have an efficiency of ~25.7%. With the TAB 10 apodizer, the efficiency will drop to 20.1%.

An updated PROP92 model for the PAM/ISP/PABTS system indicates that a regen energy at the shaper input of 4.5 mJ will be required to achieve a 16.0-J spatially shaped output at RP8, and 3.02 J at the NIF injection mirror. For ~20.6 kJ at the KDP plane, however, only ~6 Joules is required at RP8, and this requires ~1.2 mJ at the shaper input. The regen energies are based on a 5-cm Nova rod amplifier energy gain of 16.8/pass and without losses in the 4-pass cavity associated with the SSD grating. All numbers are subject to minor revision.

I'm particularly gratified that the initial PAM measurements are in agreement with my estimates,

Mark Henesian 1/7/99

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.